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Interface Specification

INNER TRIPLET QUADRUPOLE HELIUM VESSEL LMQXB AND CRYOSTAT ASSEMBLY LQXB

Abstract

This specification establishes the functional requirements for the LMQXB helium assembly, and the fully cryostatted LQXB assembly. These elements compose the Q2 inner triplet optical element at interaction regions 1, 2, 5 and 8.

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History of Changes

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0.0	2001-12-12	All	Initial draft

Table of Contents

1. OVERVIEW

The LQXB cryostatted assembly forms the as-installed Q2 optical element in the 4 interaction regions of the LHC, shown in Figure 1 and as described in the Inner Triplet Functional Specification [1]. The 3 magnetic elements of the Q2 optical element are two MQXB quadrupoles [2], and a steering dipole corrector MCBX [3], which are contained within the LMQXB helium vessel. The LMQXB, when surrounded by cryostat shields, piping, and the vacuum vessel, is then the LQXB assembly, as installed in the tunnel of the LHC.

In addition to the LQXA, LQXB, and LQXC assemblies, kits to complete the Q1/Q2 and Q2/Q3 interconnects will be installed in the LHC tunnel to complete the inner triplet system.

The MQXB design and production is the responsibility of Fermilab. The MCBX dipole corrector and beam tube are delivered from CERN. Fermilab is responsible for the design and assembly of the LMQXB vessels, and the LQXB cryostat assemblies. The interconnect assembly, with the exception of the cold bore and cold bore associated components, is the responsibility of Fermilab, though it and the the beam position monitor mounting will occur only at CERN. Interface definitions for the MQXB and MCBX magnetic elements can be found at [4] and [5], respectively.

This interface specification covers the LQXB assembly only.

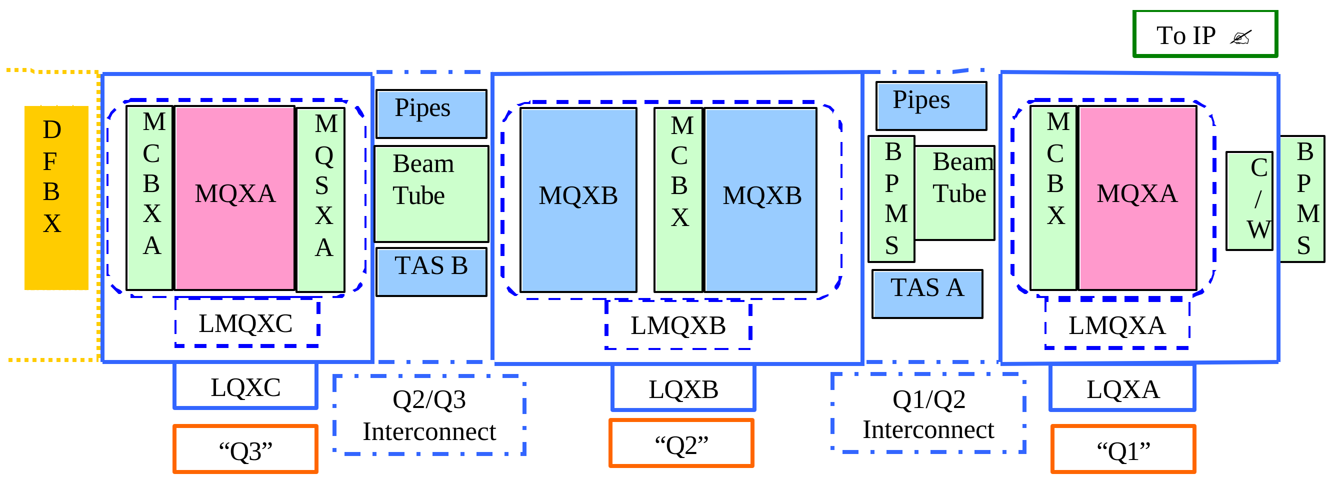

Figure 1. Inner Triplet Nomenclature.

2. GENERAL SPECIFICATIONS

Table 1 is a summary table of LQXB parameters.

Table 1. Specifications of the LBX Dipole Cryo-assemblies.

Item	*Value*
Quantity + (Spares)	8 + (1)
Operating Temperature	1.9 K
Cold Bore Tube[4] OD / ID	67 / 63 mm
Mass	17455 kg
MQXB OD	416 mm
Length (end volume – end volume)	12.58 m
Cryostat Length	12.38 m
Cryostat Diameter	914 mm
Cryostat Cross Section @ Support	1000 mm x 1100mm

3. GENERAL LAYOUT

The LBX magnet cross section at a support post location, as viewed from non-IP end, is shown in Figure 2.

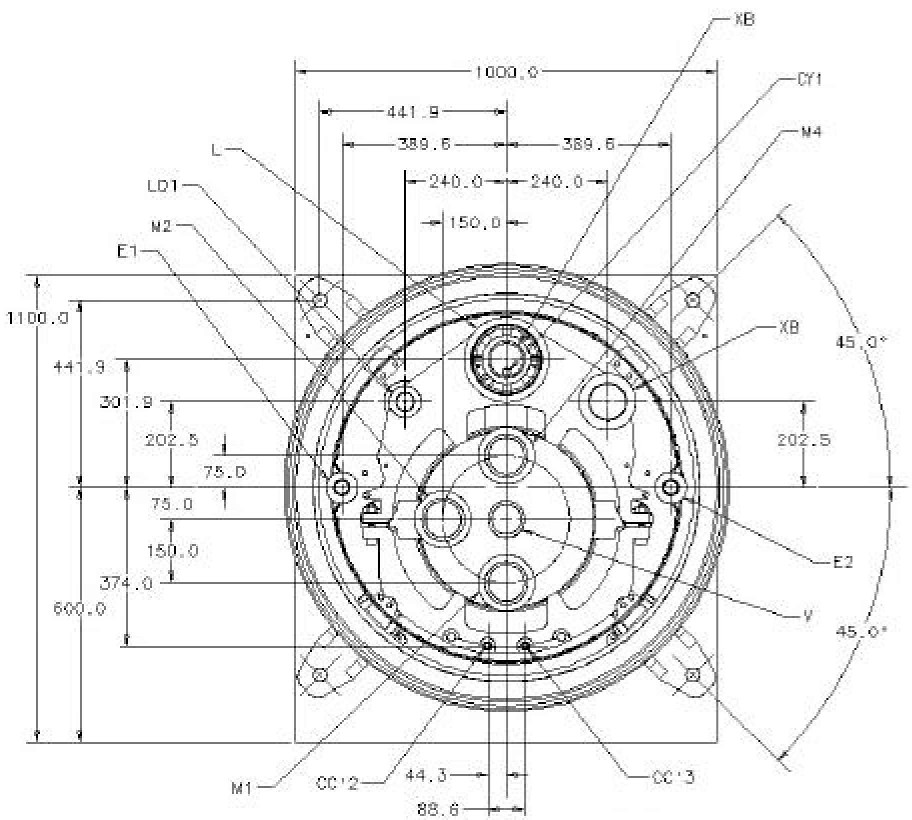

Figure 2. Assembled LQXB, looking towards the IP from the non-IP end of the magnet

The coordinate system used for the remainder of this specification has it's origin at the location of the non-IP end of the LQXB assembly. Z is defined to be vertical, originating at the beam axis; Y is along the beam axis pointing towards the IP, originating at the non-IP end of the vacuum vessel; and the X axis is then determined by the right hand rule, pointing to the right when facing the non-IP end of the LQXB, and originating at the beam axis. This local coordinate system is used independent of where the magnet will be installed in the tunnel, since in advance that position is not determined. Figure 3 shows the longitudinal postion of the origin; the X and Z locations are coincident with the beam tube axis (tube V) in Figure 2.

The coordinate system is defined in the same way for both warm and cold conditions, i.e. it is fixed on the lead end of the cold mass. This results in a displacement of the coordinate system due to thermal contraction of the cold mass and support posts. The origin is displaced 0.1 mm in the negative Z-direction (down).

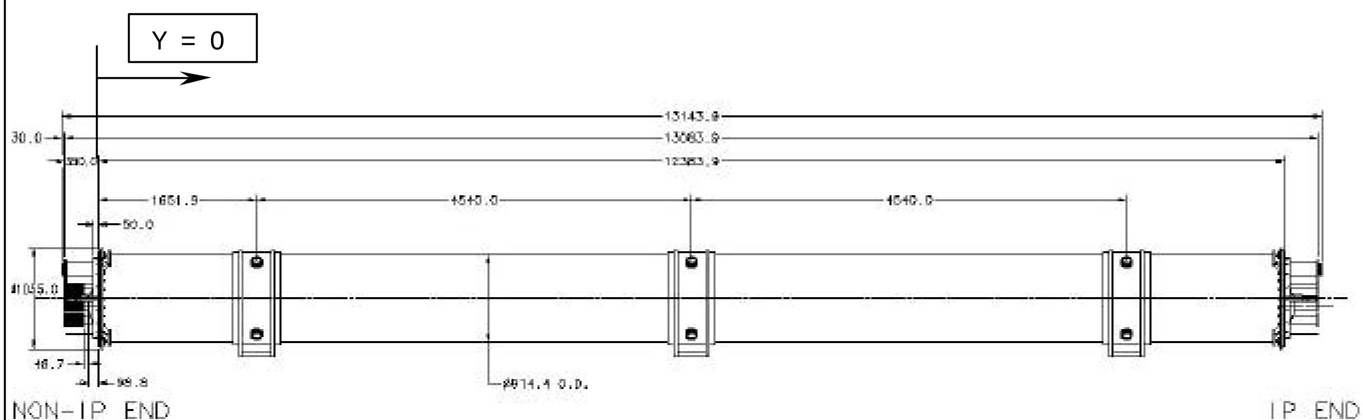

Figure 3. Longitudinal Layout of Assembled LQXB

4. LQXB INTERFACES

4.1 PIPING

The LQXB delivered assemblies are identical independent of their final position in the LHC tunnel. Changes in the operational configuration of the cryogenic circuits are accommodated at installation,and in the design of the DFBX, which is unique to each installed position.

The LQXB piping requirements are shown in the inner triplet cooling schematics, the DFBX specifications, and the LMQXB/LQXB functional specifications. Tables 2 and 3 list each piping line included in the LQXB, in the warm 'as delivered' condition. Pipe positions are taken from the Q2 Cryostat Assembly drawing [6].

Unless indicated otherwise, all piping and tubing ends are terminated with flanges, which are mounted perpendicular to the tube or pipe axis within 0.5 mm. The lengths of the pipes are cut to within 1 mm.

The M1, M2, M4 and L lines form the static pressurized 1.9K helium bath that provides the operating environment for the magnets. In addition, the main and corrector bus run through port M1; the instrumentation and control wiring through M2; M4 is left completely open for heat transport. The XB lines provide the return path for the 2 phase 1.9K helium after it passes through the external heat exchanger, while the CY1 line provides the liquid supply to the heat exchanger. The LD1 line is used for cooldown and as a relief path.

The CC lines provide 4.5K cooling which is used in the interconnects for the TAS and beam screens in the high luminosity IRs. The E lines are the supply and return for the 50-70K shield. Insulating vacuum is provides by the vacuum vessel and associated flanges (W), while the cold bore V provides the beam vacuum space.

Table 2 shows the warm coordinates for the non-IP end of the LQXB, Table 3 shows the IP end. Table 4 describes the movement for each of the pipes seen with cooldown, while Table 4 shows the 'connection map' for which pipes are utilized at which installation points.

Table 2. Warm co-ordinates for non-IP end of the LQXB assembly.

		Connection Flange		Warm Co-ordinates					
Name	**Description**	**OD(mm)**	**Ref. Dwg.**	**X (mm)**		**Z (mm)**		**Y (mm)**	
V	Cold bore tube	114	390300	0.0	±1	0.0	±1	-147.1	±1
M1	Helium Vessel Connection (bus)	134	390032	0.0	±2	-150.0	±2	-350.0	±2
M2	Helium Vessel Connection (instrumentation)	134	390032	-150.0	±2	0.0	±2	-350.0	±2
M4	Helium Vessel Connection	134	390032	0.0	±2	150.0	±2	-350.0	±2
E1	Heat Shield Supply	75	390035	-389.6	±2	75.0	±2	-350.0	±2
E2	Heat Shield Return	75	390035	389.6	±2	75.0	±2	-350.0	±2
Cc'2	Beam Screen Supply	xx	xx	-44.3	±3	-299.0	±3	-350.0	±3
Cc'3	Beam Screen Return	xx	xx	44.3	±3	-299.0	±3	-350.0	±3
XB	1.9K Vapor return	134	390032	240.0	±2	277.5	±2	-350.0	±2
XB(htxu)	1.9K Vapor return (hxtu)	114	390030	0.0	±2	376.9	±2	-380.0	±2
L	HXTU External Shell	201	390031	0.0	±3	376.9	±3	-350.0	±2
LD1	1.9K Cooldown Line	75	390033	-240	±3	277.5	±3	-350.0	±2
CY1	1.9K Liquid Line	xx	xx	0.0		~350.0		-350.0	
W	Cryostat (rotating flange)	1055	390022	0.0	±3	75.0	±3	0.0	±3
W'	Cryostat (flange mount)	1009.6	390020	0.0	±3	75.0	±3	0.0	±3

Table 3. Warm co-ordinates for IP end of the LQXB assembly.

		Connection Flange		Warm Co-ordinates					
Name	**Description**	**OD (mm)**	**Ref. Dwg.**	**X (mm)**		**Z (mm)**		**Y (mm)**	
V	Cold bore tube[a]	114	390300	0.0	±1	0.0	±1	12531.3	±1
M1	Helium Vessel Connection (bus)	134	390032	0.0	±2	-150.0	±2	12733.9	±2
M2	Helium Vessel Connection (instrumentation)	134	390032	-150.0	±2	0.0	±2	12733.9	±2
M4	Helium Vessel Connection	134	390032	0.0	±2	150.0	±2	12733.9	±2
E1	Heat Shield Supply	75	390035	-389.6	±2	75.0	±2	12733.9	±2
E2	Heat Shield Return	75	390035	389.6	±2	75.0	±2	12733.9	±2
Cc'2	Beam Screen Supply	xx	xx	-44.3	±3	-299.0	±3	12733.9	±3
Cc'3	Beam Screen return	xx	xx	44.3	±3	-299.0	±3	12733.9	±3
XB	1.9K Vapor return	134	390032	240.0	±2	277.5	±2	12733.9	±2
XB(hxtu)	1.9K Vapor return (hxtu)	114	390030	0.0	±2	376.9	±2	12763.9	±2
L	HXTU External Shell	201	390031	0.0	±3	376.9	±3	12733.9	±2
LD1	1.9K Cooldown Line	75	390033	-240	±3	277.5	±3	12733.9	±2
CY1	1.9K Liquid Line	xx	xx	0.0		~350.0		12733.9	
W	Cryostat (rotatable flange)[a]	1055	390022	0.0	±3	75.0	±3	12383.9	±3
W'	Cryostat (flange mount)[a]	1009.6	390020	0.0	±3	75.0	±3	12383.9	±3

Table 4. Cold movements due to cooldown. The origin of the cold co-ordinate system is displaced 0.1 mm in the negative Z-direction with respect to the warm co-ordinate system.

Name	**Description**	**Movement[a]**
V	Cold bore tube	X: moves 0.3% toward origin (cold mass center) Z: moves 0.3% toward origin (cold mass center), origin moves 0.1 mm in negative Z-direction (down) Y: moves 0.3% toward longitudinal fix point, located at Y = 6191.9mm
M1, M2, M4	Helium vessel connection	
CY1	1.9 K liquid line	
XB	1.9K vapor return	
CC'2, CC'3	4.5 K helium supply	
E1, E2	Heat shield	
L	HXTU external shell	
LD1	1.9K cooldown line	

Table 5. Installation of Piping by Location. Pipes not listed are installed at every location.

		Installed Location							
Name	**Description**	**IR1L**	**IR1R**	**IR2L**	**IR2R**	**IR5L**	**IR5R**	**IR8L**	**IR8R**
Cc'2	Beam Screen Supply	Yes	Yes	No	No	Yes	Yes	No	No
Cc'3	Beam Screen return	Yes	Yes	No	No	Yes	Yes	No	No
XB	1.9K Vapor return	No	Yes	No	Yes	Yes	No	No	Yes
CY1	1.9K Liquid Line	Yes	No	Yes	No	No	Yes	Yes	No

4.2 ELECTRICAL CONNECTIONS

Figure 4 is a schematic diagram of the bus work and instrumentation for the LQXB. The chart is grouped horizontally by longitudinal position and vertically by helium vessel connection. The M1 connection is used for high current and corrector bus work while M2 is used for instrumentation wires and heater leads. The curved lines on either side of the LQXB represents the end domes. Bus and wire to the exiting the left enddome form the LQXB-LQXC interconnect, bus and wires to the right form the LQXB-LQXA interconnect.

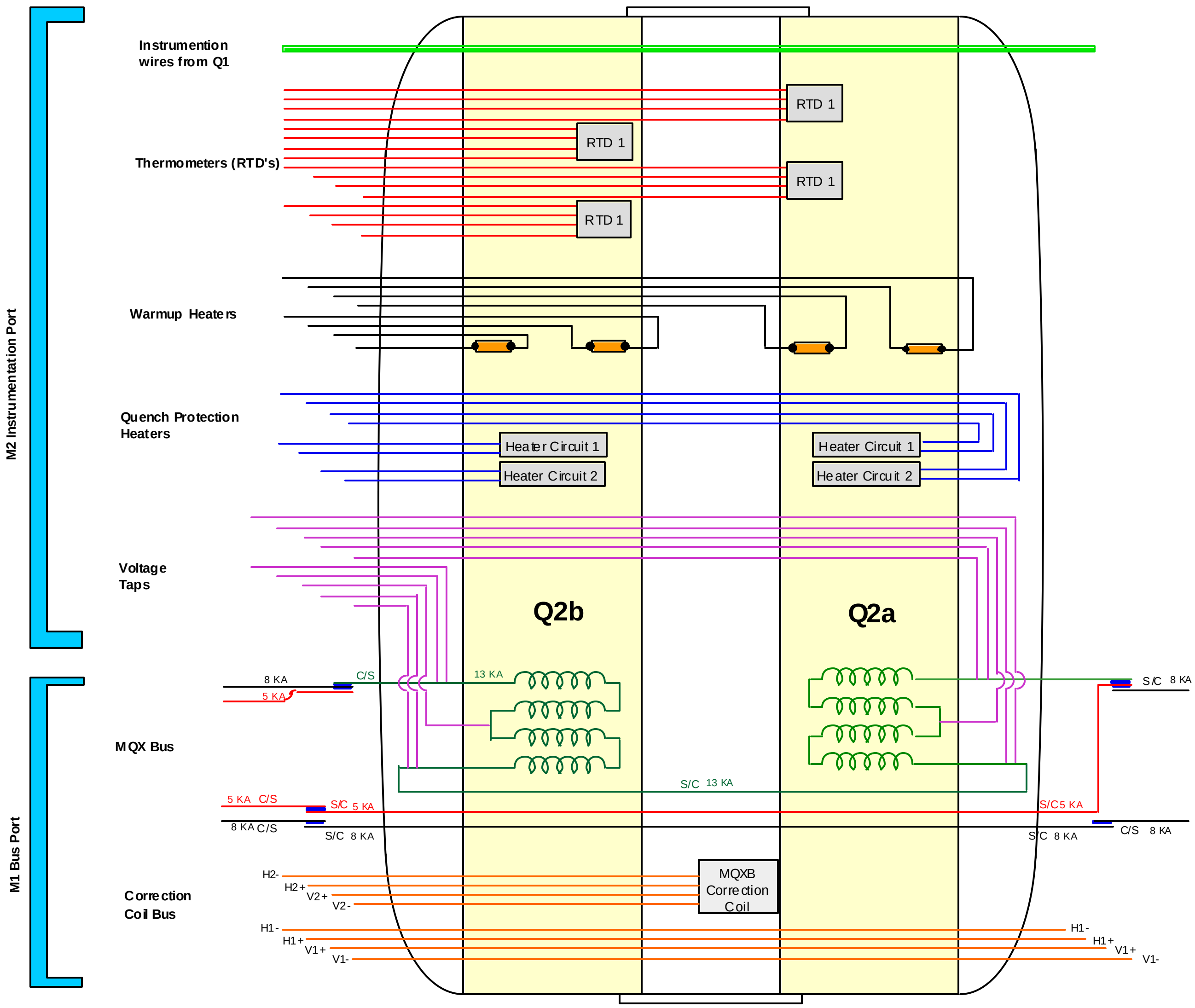

Figure 4. Electrical schematic of the LQXB magnet.

The high current MQX bus work consists of a MQXB inner coil cable stablized by either another inner coil cable of a copper cable of the same cross section. The fixed point for the bus work is located on the nonlead end plate of the MQXB Q2b. There are 3 busses in LQXB. Two of the busses ("5kA" and "8 kA") act as a current return path for the inner triplet. The “13kA” bus connects together the two MQXB “B” leads, as defined by the CERN powering convention [7]. The 13kA bus is soldered to the leads in the end dome. There is an expansion loop in each enddome to accommodate the differences in thermal contraction between the bus work and the cold mass.

The splices for the “5ka” and “8ka” buses as well as the correction coil buses occur in the interconnect region, as shown in figure 5. Each MQXB bus splice will be individually wrapped in polyimide, and separated by a 0.25 mm g-11 CR sheet. The whole bus assembly will be wrapped with polyimide for mechanical support. The corrector bus will be spliced or welded together and supported by a g-11 CR piece as shown.

Thermal expansion for these busses are accounted for by expansion loops in the LQXC and LQXA. The bus will be adequately supported in the interconnect region by the LQXB bus housing and a spider assembly on the LQXA(C) side of the interconnect

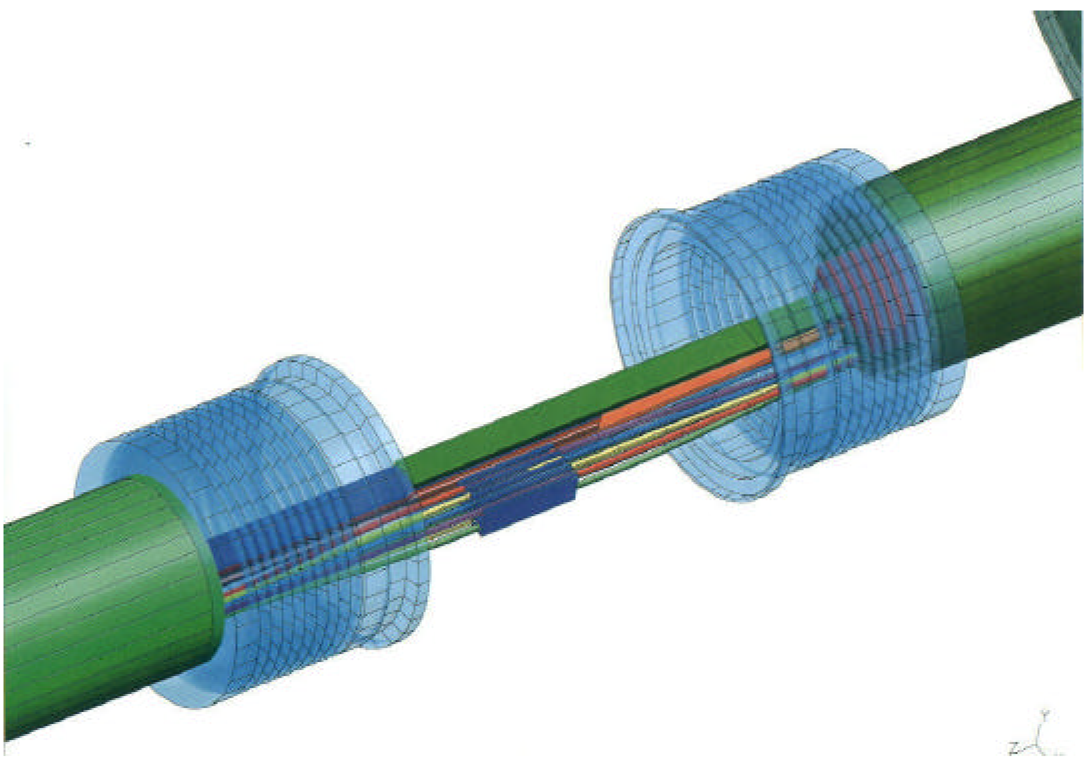

Figure 5 Longitudinal view of LQXB to LQXA bus at the interconnect region.

The instrumentation and control wiring required for the LQXB is listed in Table 6. This includes quench protection heater leads (H), leads for 50 W warmup heater (W), voltage taps (VT) and RTD's (T). Quench protection heater leads and warmup heaters leads are 20 Gauge polyimide coated wire, voltage taps are 26 Gauge polyimide wires and thermometer leads are 30 gauge polyimide coated wire. All instrumentation and control wiring inside the end volume is routed through the LMQXB back to the DFBX, where the wiring for the inner triplet is routed to room temperature en masse. Thus wiring from LQXA is routed through LQXB.

There are two temperature sensors located on the return end plate of each cold mass. One of these sensors is redundant. Temperature sensors are the short type thermometer assemblies (36 mm x 12 mm x 4.2 mm) typically used by CERN [8]. The assemblies will be calibrated and supplied to BNL by CERN.

A 50 W warm up heater is attached to each of the four MQXB end plates. Each heater is independently powered. The heating requirement of the LQXB is 100 W, thus there is a two fold redundancy in these warmup heaters.

Table 6 Instrumentation and Control Wiring

Wire	Description	Wire	Description
VTa1Q1	Q1 Lead Voltage Tap "a", primary	Ha1Q1	Q1 Heater Lead "a", 1-2 & 3-4 circuit heater
VTa2Q1	Q1 Lead Voltage Tap "a",redundant	Ha2Q1	Q1 Heater Lead "a", 1-4 & 2-3 circuit heater
VTb1Q1	Q1 Lead Voltage Tap "b", primary	Hb1Q1	Q1 Heater Lead "b", 1-2 & 3-4 circuit heater
VTb2Q1	Q1 Lead Voltage Tap "b",redundant	Hb2Q1	Q1 Heater Lead "b", 1-4 & 2-3 circuit heater
VTc1Q1	Q1 Center Voltage Tap "c", primary	Ha1Q2a	Q2a Heater Lead "a", 1-2 & 3-4 circuit heater
VTc2Q1	Q1 Center Voltage Tap "c", redundant	Ha2Q2a	Q2a Heater Lead "a", 1-4 & 2-3 circuit heater
VTa1Q2a	Q2a Lead Voltage Tap "a", primary	Hb1Q2a	Q2a Heater Lead "b", 1-2 & 3-4 circuit heater
VTa2Q2a	Q2a Lead Voltage Tap "a", redundant	Hb2Q2a	Q2a Heater Lead "b", 1-4 & 2-3 circuit heater
VTb1Q2a	Q2a Lead Voltage Tap "b", primary	Ha1Q2b	Q2b Heater Lead "a", 1-2 & 3-4 circuit heater
VTb2Q2a	Q2a Lead Voltage Tap "b", redundant	Ha2Q2b	Q2b Heater Lead "a", 1-4 & 2-3 circuit heater
VTc1Q2a	Q2a Center Voltage Tap "c", primary	Hb1Q2b	Q2b Heater Lead "b", 1-2 & 3-4 circuit heater
VTc2Q2a	Q2a Center Voltage Tap "c", redundant	Hb2Q2b	Q2b Heater Lead "b", 1-4 & 2-3 circuit heater
VTa1Q2b	Q2b Lead Voltage Tap "a", primary	TaQ21_I+	Q1 RTD, primary
VTa2Q2b	Q2b Lead Voltage Tap "a", redundant	TaQ21_I-	
VTb1Q2b	Q2b Lead Voltage Tap "b", primary	TaQ21_V+	
VTb2Q2b	Q2b Lead Voltage Tap "b", redundant	TaQ21_V-	
VTc1Q2b	Q2b Center Voltage Tap "c", primary	TbQ21_I+	Q1 RTD, redundant
VTc2Q2b	Q2b Center Voltage Tap "c", redundant	TbQ21_I-	
VTH1	Corrector Q1-H1 Voltage Tap	TbQ21_V+	
VTV1	Corrector Q1-V1 Voltage Tap	TbQ21_V-	
VTH2	Corrector Q2-H2 Voltage Tap	TaQ2a_I+	Q2a RTD, primary
VTV2	Corrector Q2-V2 Voltage Tap	TaQ2a_I-	
Wa1Q1	Q1 Warmup Heater Lead "a", lead end heater	TaQ2a_V+	
Wa2Q1	Q1 Warmup Heater Lead "a", return end heater	TaQ2a_V-	
Wb1Q1	Q1 Warmup Heater Lead "b", lead end heater	TbQ2a_I+	Q2a RTD, redundant
Wb2Q1	Q1 Warmup Heater Lead "b", return end heater	TbQ2a_I-	
Wa1Q2a	Q2a Warmup Heater Lead "a", lead end heater	TbQ2a_V+	
Wa2Q2a	Q2a Warmup Heater Lead "a", return end heater	TbQ2a_V-	
Wb1Q2a	Q2a Warmup Heater Lead "b", lead end heater	TaQ2b_I+	Q2b RTD, primary
Wb2Q2a	Q2a Warmup Heater Lead "b", return end heater	TaQ2b_I-	
Wa1Q2b	Q2b Warmup Heater Lead "a", lead end heater	TaQ2b_V+	
Wa2Q2b	Q2b Warmup Heater Lead "a", return end heater	TaQ2b_V-	
Wb1Q2b	Q2b Warmup Heater Lead "b", lead end heater	TbQ2b_I+	Q2b RTD, redundant
Wb2Q2b	Q2b Warmup Heater Lead "b", return end heater	TbQ2b_I-	
		TbQ2b_V+	
		TbQ2b_V-	

Connections of the instrumentation and control wiring are made using Hypertronics connectors, which are completed and fully tested at fermilab before shipment to CERN. The pin layout for the connector is described in in Figure 5 and Table 7. The connectors male (pin) connector will be attached to the "side facing LQXC, the female connector attached to the side facing LQXA. The LQXC connector will be mounted from a bracket on the LQXB end dome. Both the LQXA and LQXC connections are designed for adequate strain relief and compensation for thermal contraction.

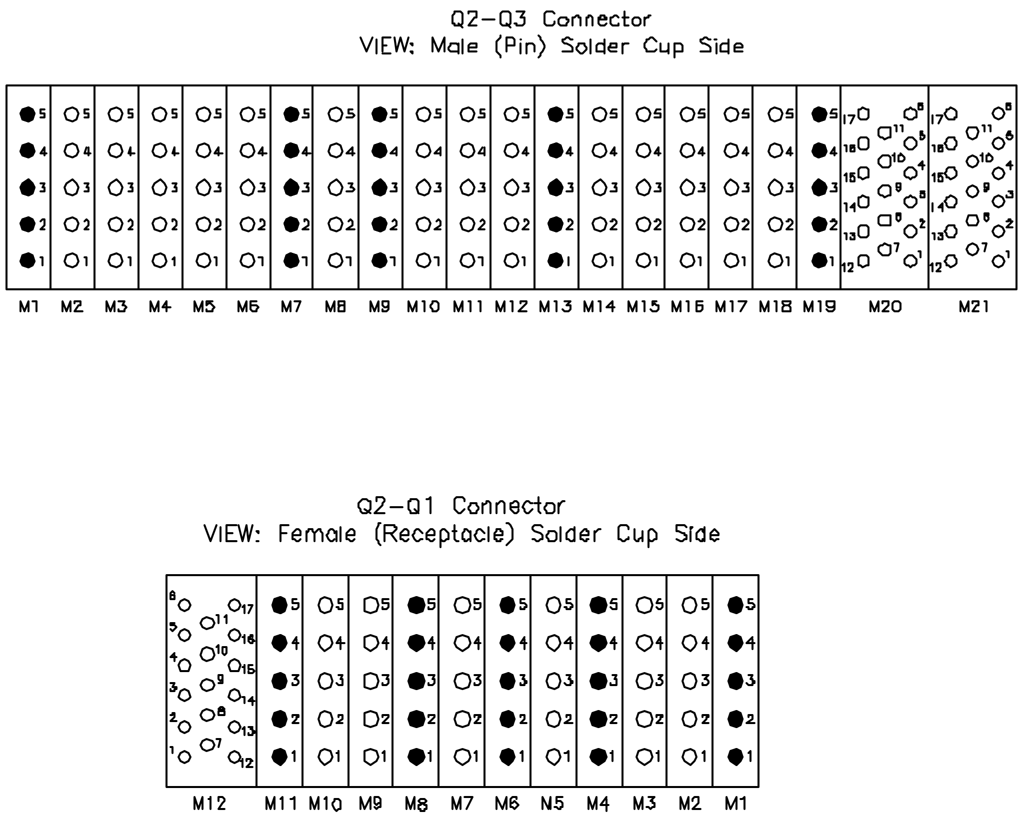

Figure 6. Pin configuration for Hypertronics Connector

Table 7 Pin assignments for Hypertronics connectors.

Q1(male)-Q2(female) Connector

Module	Pin	Wire	Module	Pin	Wire
M1	1		M7	1	Wa1Q1
M1	2		M7	2	Wb1Q1
M1	3		M7	3	Wa2Q1
M1	4		M7	4	Wb2Q1
M1	5		M7	5	Empty
M2	1	VTa1Q1	M8	1	
M2	2	VTa2Q1	M8	2	
M2	3	VTc1Q1	M8	3	
M2	4	VTc2Q1	M8	4	
M2	5	VTb1Q1	M8	5	
M3	1	Empty	M9	1	Ha1Q1
M3	2	Empty	M9	2	Empty
M3	3	Empty	M9	3	Hb1Q1
M3	4	Empty	M9	4	Empty
M3	5	VTb2Q1	M9	5	Ha2Q1
M4	1		M10	1	Empty
M4	2		M10	2	Empty
M4	3		M10	3	Empty
M4	4		M10	4	Hb2Q1
M4	5		M10	5	Empty
M5	1	VTH1	M11	1	
M5	2	VTV1	M11	2	
M5	3	Empty	M11	3	
M5	4	Empty	M11	4	
M5	5	Empty	M11	5	
M6	1		M12	1	TaQ1_I+
M6	2		M12	2	TaQ1_I-
M6	3		M12	3	TaQ1_V+
M6	4		M12	4	TaQ1_V-
M6	5		M12	5	TbQ1_I+
			M12	6	TbQ1_I-
			M12	11	TbQ1_V+
			M12	10	TbQ1_V-
			M12	9	Empty
			M12	8	Empty
			M12	7	Empty
			M12	12	Empty
			M12	13	Empty
			M12	14	Empty
			M12	15	Empty
			M12	16	Empty
			M12	17	Empty

Q2(male)-Q3(female) Connector

Module	Pin	Wire	Module	Pin	Wire	Module	Pin	Wire
M1	1		M9	1		M17	1	Empty
M1	2		M9	2		M17	2	Hb1Q2b
M1	3		M9	3		M17	3	Empty
M1	4		M9	4		M17	4	Ha1Q2b
M1	5		M9	5		M17	5	Empty
M2	1	VTa1Q1	M10	1	Wa1Q1	M18	1	Ha2Q2b
M2	2	VTa2Q1	M10	2	Wb1Q1	M18	2	Empty
M2	3	VTc1Q1	M10	3	Wa2Q1	M18	3	Hb2Q2b
M2	4	VTc2Q1	M10	4	Wb2Q1	M18	4	Empty
M2	5	VTb1Q1	M10	5	Empty	M18	5	Empty
M3	1	VTc1Q2a	M11	1	Wa1Q2a	M19	1	
M3	2		M11	2	Wb1Q2a	M19	2	
M3	3	VTa2Q2a	M11	3	Wa2Q2a	M19	3	
M3	4	VTa1Q2a	M11	4	Wb2Q2a	M19	4	
M3	5	VTb2Q1	M11	5	Empty	M19	5	
M4	1	VTc2Q2a	M12	1	Wa1Q2b	M20	1	TaQ21_I+
M4	2		M12	2	Wb1Q2b	M20	2	TaQ21_I-
M4	3	VTb1Q2a	M12	3	Wa2Q2b	M20	3	TaQ21_V+
M4	4	VTb2Q2a	M12	4	Wb2Q2b	M20	4	TaQ21_V-
M4	5	VTb1Q2b	M12	5	Empty	M20	5	TbQ21_I+
						M20	6	TbQ21_I-
M5	1		M13	1		M20	11	TbQ21_V+
M5	2	VTc2Q2b	M13	2		M20	10	TbQ21_V-
M5	3	VTc1Q2b	M13	3		M20	9	TaQ2a_I+
M5	4		M13	4		M20	8	TaQ2a_I-
M5	5	VTb2Q2b	M13	5		M20	7	TaQ2a_V+
						M20	12	TaQ2a_V-
M6	1	VTa1Q2b	M14	1	Ha1Q1	M20	13	TbQ2a_I+
M6	2	VTa2Q2b	M14	2	Empty	M20	14	TbQ2a_I-
M6	3	Empty	M14	3	Hb1Q1	M20	15	TbQ2a_V+
M6	4	Empty	M14	4	Empty	M20	16	TbQ2a_V-
M6	5	Empty	M14	5	Ha2Q1	M20	17	
M7	1		M15	1	Empty	M21	1	TaQ2b_I+
M7	2		M15	2	Ha1Q2a	M21	2	TaQ2b_I-
M7	3		M15	3	Empty	M21	3	TaQ2b_V+
M7	4		M15	4	Hb2Q1	M21	4	TaQ2b_V-
M7	5		M15	5	Empty	M21	5	TbQ2b_I+
						M21	6	TbQ2b_I-
M8	1	VTH1	M16	1	Hb1Q2a	M21	11	TbQ2b_V+
M8	2	VTV1	M16	2	Empty	M21	10	TbQ2b_V-
M8	3	VTH2	M16	3	Ha2Q2a	M21	9	Empty
M8	4	VTV2	M16	4	Empty	M21	8	Empty
M8	5	Empty	M16	5	Hb2Q2a	M21	7	Empty
						M21	12	Empty
						M21	13	Empty
						M21	14	Empty
						M21	15	Empty
						M21	16	Empty
						M21	17	Empty

5. LQXB – TUNNEL FLOOR INTERFACES

Figure 7 is a bottom view of the cryostat, showing the bottom of the support at the location internal support spider. These are located at 3 locations along the length of the LQXB, 4540 mm on either side of the center support, as seen in Figure 3.

To support the cryostatted magnet, CERN jacks will be used between the floor and the bottom surface of the support at each of the 3 locations. The floor jacks are not capable of resisting axial loads resulting from unbalanced bellows forces due primarily to the vacuum load. These loads are transmitted back to the DFBX by the tie rods which span each interconnect.

Handling points and overall envelope of the LQXB assembly are described in [9].

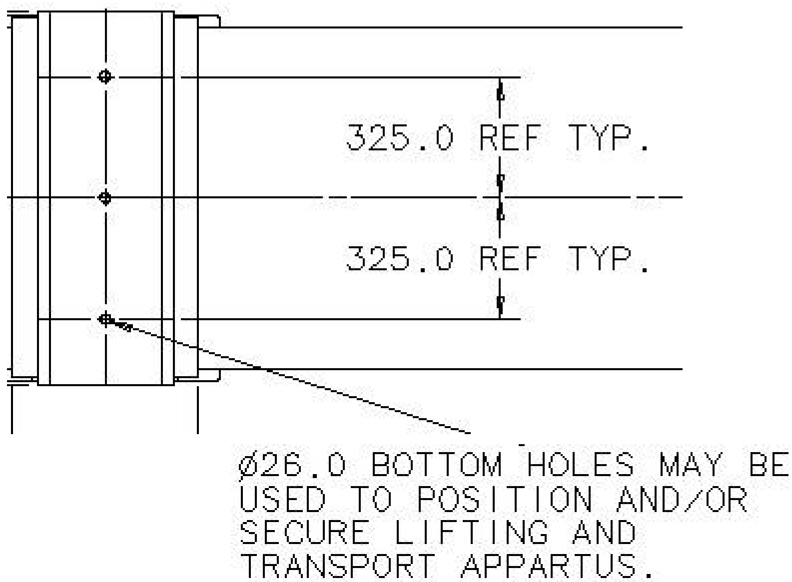

Figure 7. Jack locations on the bottom of the LQXB cryostat. Dimensions are in mm.

6. LBX – ALIGNMENT SYSTEM INTERFACES

The location of the magnetic field center of the cold mass within the vacuum vessel is known by taking a single stretched wire measurement of the magnetic axis, both warm and cold, and directly transferring it to fiducial balls that are located on the cryostat support reinforcements. The cryostat will also have twelve fiducial cups for the Taylor-Hobson (T-H) spheres in accordance with the CERN preferred method of surveying. The documentation package shipped with each magnet will include the survey information taken during manufacture.

The nominal locations of the fiducials with respect to the magnetic axis of the dipole are given in Figures 2 and 3.

7. REFERENCES

[1] Inner Triplet Systems at IR1, 2, 5, AND 8, CERN Functional Specification LHC-LQX-ES-0001.

[2] LHC Functional Specification, “Inner Triplet Quadrupole MQXB,” LHC-LQX-ES-0002.

[3] LHC Specification, “Supply of Superconducting Dipole Corrector Magnets MCBX for the Inner Triplets of the Large Hadron Collider,” LHC-MCBX-CI-0001, with updates in Change order LHC-MC-EC-0001.

[4] LHC Interface Specification, “Inner Triplet Quadrupole MQXB,” LHC-LQX-ES-0003.

[5] LHC Interface Specification, “Inner Triplet Corrector MCBX/MCBXA,” LHC-LQX-ES-0005.

[6] LHC IRQ Cryostat Q2 Interface and Assembly, FNAL Drawing number 5520-ME-390266

[7] LHC Magnet Polarities, CERN Specification LHC-DC-ES-0001.00, rev 1.1, 27 April 1999.

[8] Engineeering Specification, “Installation Guide for LHC Cryogenic Thermometers”, LHC-QIT-ES-0002

[9] LHC IRQ Cryostat Q2 Lifting and Transport Interface, FNAL Drawing number 5520-ME-390298